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by
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Fisheries Research Division
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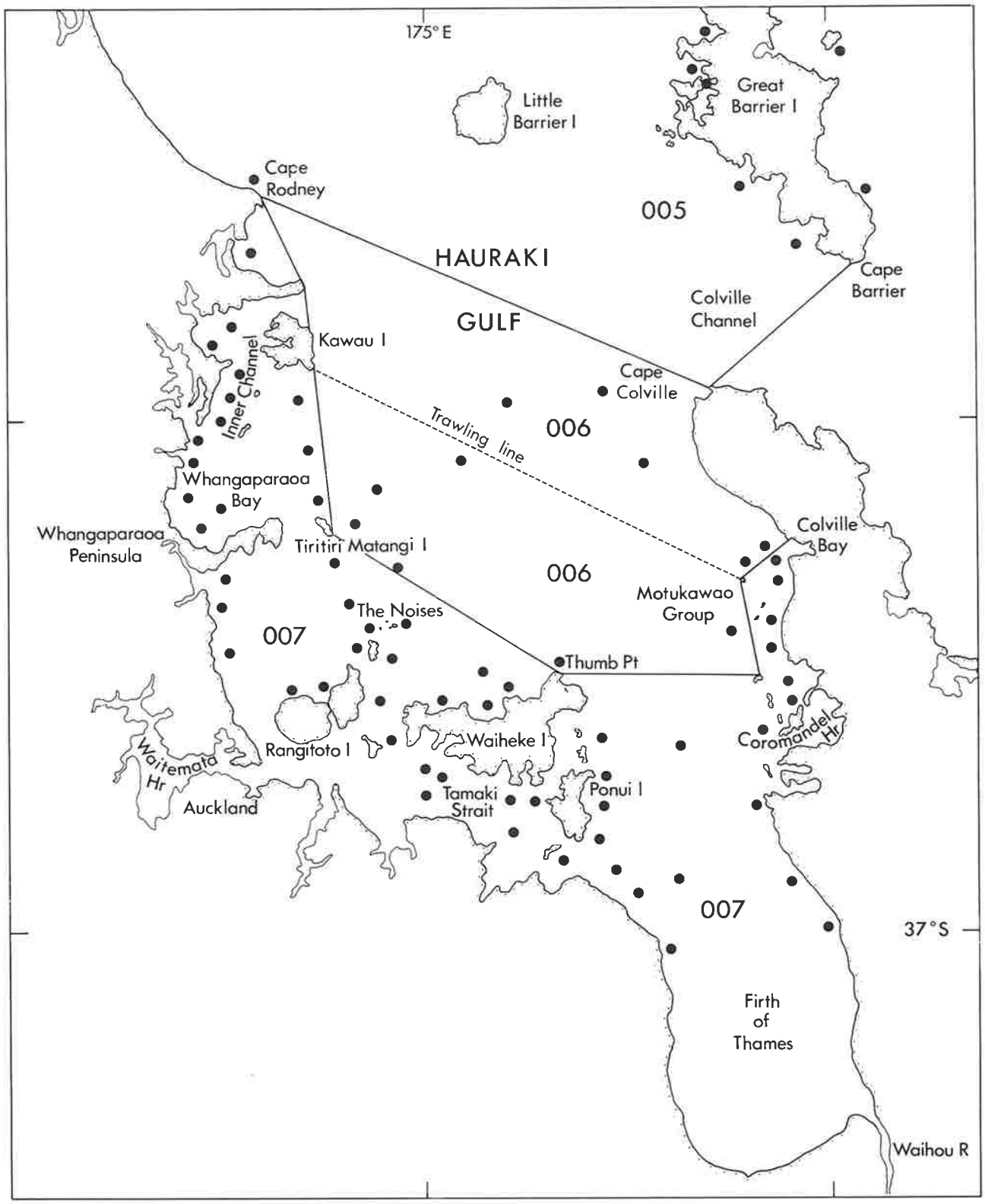


Fig. 1: The Hauraki Gulf, showing tagging sites (solid circles), places mentioned in the text, and the boundaries of fisheries statistical areas.

Introduction

During 1974–77 an extensive snapper tagging programme was carried out in the Hauraki Gulf area. The initial objectives were to devise suitable methods of catching snapper, *Chrysophrys auratus* (Forster), in good condition for tagging and to test the suitability of different types of tags. Experiments showed that snapper could be successfully tagged by use of the canvas cod-end technique (Crossland 1976) or they could be tagged under water by scuba divers (Tong 1978). Spaghetti tags, either lock-on or tied, were found to be satisfactory (Crossland 1976, Tong 1978). Most tagging was done with the canvas cod-end and lock-on tags, as this was the most economical method in time and manpower.

Other objectives of the programme were to study the movements of tagged fish and to estimate exploitation rate and population size in the Hauraki Gulf. Returns of fish tagged in 1976 were used for estimating exploitation rate and population size (Crossland 1980a) and some information on movements was given by Crossland (1976) and Tong (1978). This publication describes the movements of all tagged snapper recaptured and returned over the period 1974–79 and investigates the relative importance and seasonal trends of the different fishing methods in the Hauraki Gulf snapper fishery.

Tagging

Nine tagging cruises were made in the Hauraki Gulf area between February 1974 and October 1977 (Table 1) and 13 370 snapper were tagged. Tagging was carried out at many locations (Fig. 1), but most was done in the inner Hauraki Gulf (fisheries statistical areas 006 and 007). The canvas cod-end technique was used on all cruises except one; details of this method and the tags used are given by Crossland (1976). Tagging by scuba divers, which was used on the September 1975 cruise, is described by Tong (1978).

For each returned tag the following information was requested from the finder: date, place, and method of recapture and fork length of fish.

TABLE 1: Snapper tagging cruises in the Hauraki Gulf, 1974–77

Date	Tagging area	No. tagged	No. returned	% returned
Feb '74	Great Barrier Island, eastern gulf	1 031	33	3.2
Aug '74	North-western gulf	729	11	1.5
Oct '74	Throughout inner gulf*	1 440	41	2.8
Aug '75	Great Barrier Island	832	21	2.5
Sep '75	Inner gulf	697	52	7.5
Jun '76	Throughout inner gulf	1 743	105	6.0
Oct '76	Throughout inner gulf	2 685	217	8.1
Jun '77	Throughout inner gulf	1 790	116	6.5
Oct '77	Throughout inner gulf	2 423	111	4.6
		13 370	707	

*Fishery statistical areas 006 and 007.

Returns

Seven hundred and seven tags were returned from the 9 cruises (Table 1). Tags were recovered from 1 to 1045 days after tagging, but most were returned in the first year and very few later than the second year. Returns ceased after September 1979. The effect of tag loss on return rate is described by Crossland (1980a).

Return information was not complete for all tags recovered. The most commonly missing information was the recapture position. Sometimes an approximate position was given; for example, "between Tiri and the Noises". In such instances the position was plotted mid way between the 2 named features. Also lacking at times was an accurate date of recapture. When possible, approximations were used; for example, "during October" was recorded as being recaptured on 15 October. In a few instances recapture information was given, but the tag number was illegible or missing. Despite these problems, good data were obtained on 609 returns and some useful data on most of the remaining 98 returns.

To investigate whether size of a tagged fish had any effect on its chances of being recaptured (all tagged fish were above the then legal size limit of 25 cm), size-frequency data of recaptured fish from the June 1976 cruise were compared with those fish tagged during that cruise. There was no obvious difference between the shapes of the histograms of the 2 sets of data. Almost half (839, or 48.5%) of the tagged fish were between 25 and 32 cm fork length and 890, or 51.5%, were 33 cm or more. The number of returns of smaller fish (42) was proportionally less than the number of returns of larger fish (60), but this difference was not significant at the 5% level when tested by the chi-square method.

The pattern of returns could also have been affected by the variable availability of tags in different months of the year due to "pulses" of tags being added to the tag pool at each tagging cruise. Availability is probably most affected by the different numbers of tags added, the unequal times between cruises, and subsequent tag loss (shedding of tags and tagging mortality). To investigate this, the number of tags available each month over the period 1974–79 was estimated, with allowance for the tag loss rate determined previously (Crossland 1980a). From these data a tag availability index was calculated by dividing the monthly totals of tags available by their average. This index (which varied from 0.77 in May to 1.3 in November) and its effect when applied to the monthly returns are shown in Fig. 2. The adjusted monthly return percentages showed a smaller range of values (4.0–14.8) than the crude return percentages (3.3–16.2), but the adjusted curve did not alter the general seasonal pattern. It was therefore concluded that the crude returns could be used in the analysis of temporal trends.

Recaptures by fishing method

Returns of tagged snapper by different fishing methods are shown in Table 2. There was considerable variation in the numbers and proportions recovered from the different tagging areas (for example, tagging at Great Barrier Island favoured returns by long-line and amateur fishermen), and results may also have been affected by the month of tagging. However, the results of the October cruises in 1974, 1976, and 1977, which are directly comparable, also showed variation. There were proportionally fewer tags returned by Danish seiners from fish tagged in 1975, 1976, and 1977 than from those tagged in 1974. Conversely, there was a greater proportion returned by long-liners and set netters in the later years. Since the pattern of tag returns over time was similar from each tagging cruise, and all returns had ceased by September 1979, this change in proportions reflects a change in fishing patterns in the Hauraki Gulf over the study period.

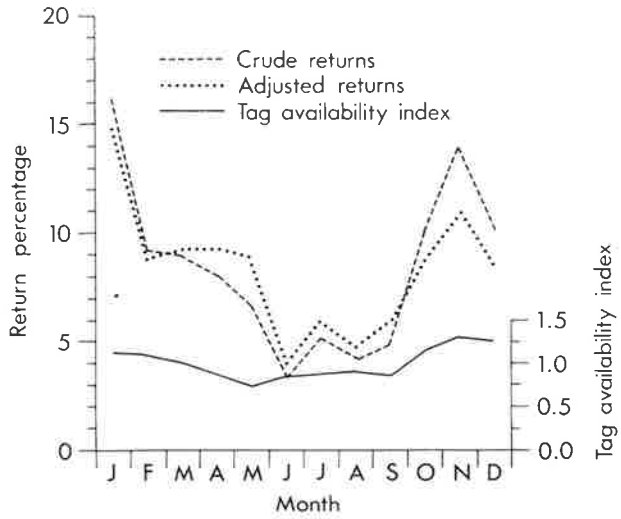


Fig. 2: The effect of tag availability on monthly tag return percentages of snapper tagged and recaptured in the Hauraki Gulf during 1974–79.

Excluding tags recovered by the research vessel, or where the recapture method was unknown, the average proportions returned by the different methods were: Danish seine 33%, long-line 28%, set net 11%, trawl 4%, other commercial 0.4%, and amateur 23%. A few tags were returned from fish sheds or shops; 2 were recovered as far away as Melbourne, Australia.

Tag returns from the 4 main fishing methods showed distinct seasonal trends (Fig. 3). There were spring peaks in returns from long-liners (October) and Danish seiners (November). Set-net and amateur returns showed an early summer peak (January).

Positions of recaptured fish

The known positions of all recaptures from the Hauraki Gulf from 1974 to 1979, grouped by date of recapture into 2-monthly periods, are shown in Fig. 4. The recaptures plotted in the centre of the Firth of Thames are those for which the only position given was "Firth of Thames".

Recaptures during January and February (136) and March and April (106) were similarly distributed, largely in the southern part of the gulf and along the eastern and western shorelines.

In May and June there were 61 recaptures. The reduction in numbers was due to the absence of returns from the Firth of Thames and fewer from Tamaki Strait. In the other parts of the gulf the

TABLE 2: Recaptures by different fishing methods of snapper tagged in the Hauraki Gulf during 1974–77; percentage values, shown in parentheses, do not include recaptures by the research vessel

Date of tagging cruise	Danish seine	Long-line	Set net	Trawl	Other commercial	Amateur	Unknown	Research vessel
1974 Feb	15 (50)	6 (20)	1 (3)	4 (13)	0 (0)	4 (13)	0 (0)	3
Aug	2 (18)	2 (18)	0 (0)	2 (18)	0 (0)	2 (18)	3 (27)	0
Oct	20 (49)	7 (17)	3 (7)	0 (0)	0 (0)	9 (22)	2 (5)	0
1975 Aug	1 (5)	6 (30)	1 (5)	0 (0)	0 (0)	12 (60)	0 (0)	1
Sep	11 (22)	25 (51)	9 (18)	0 (0)	0 (0)	1 (2)	3 (6)	3
1976 Jun	35 (36)	24 (25)	16 (17)	1 (1)	0 (0)	18 (19)	2 (2)	9
Oct	67 (31)	48 (22)	43 (20)	1 (0.5)	1 (0.5)	46 (21)	8 (4)	3
1977 Jun	41 (38)	24 (22)	12 (11)	0 (0)	0 (0)	25 (23)	6 (6)	8
Oct	30 (27)	30 (27)	16 (14)	0 (0)	3 (3)	21 (19)	11 (10)	0

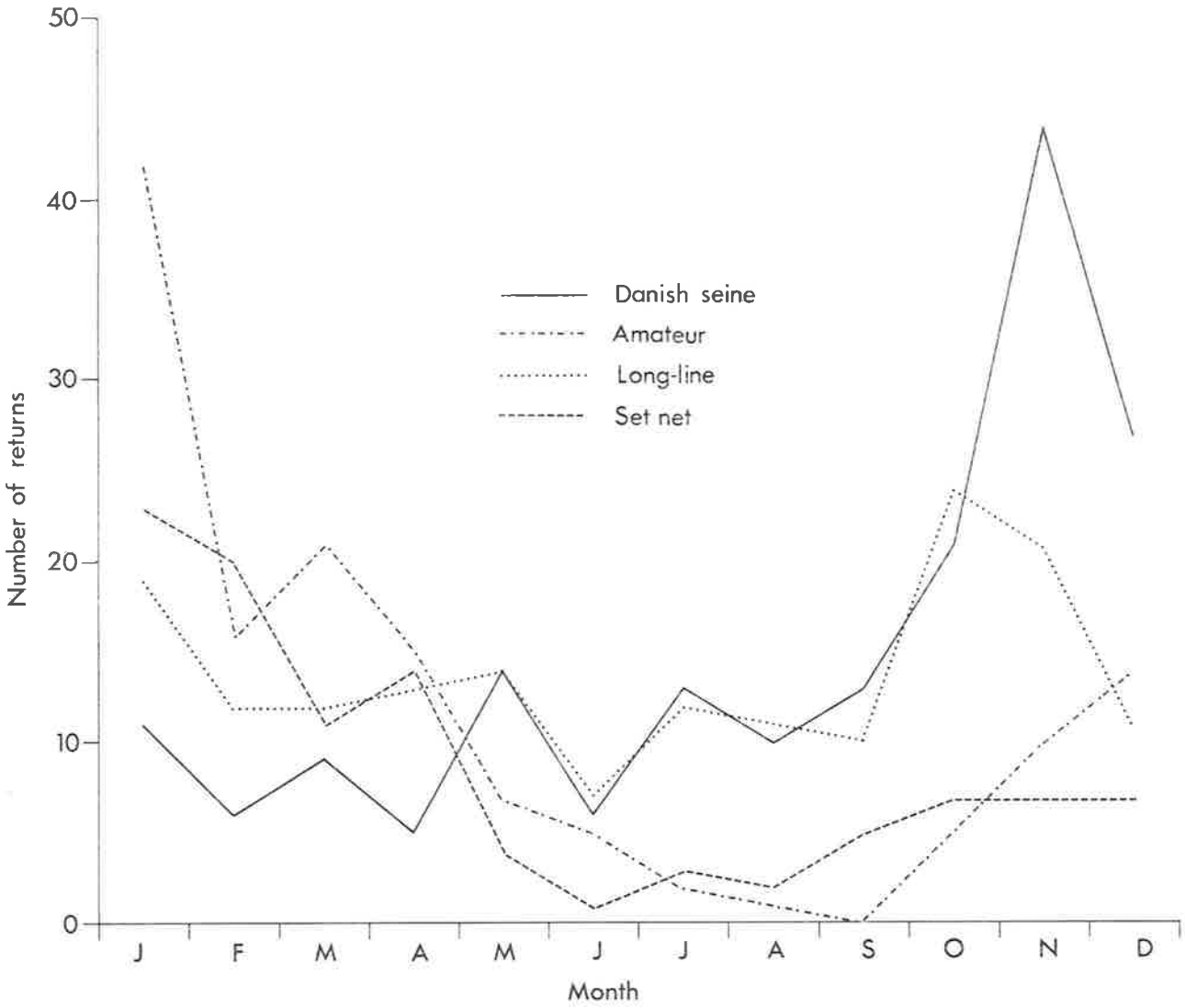
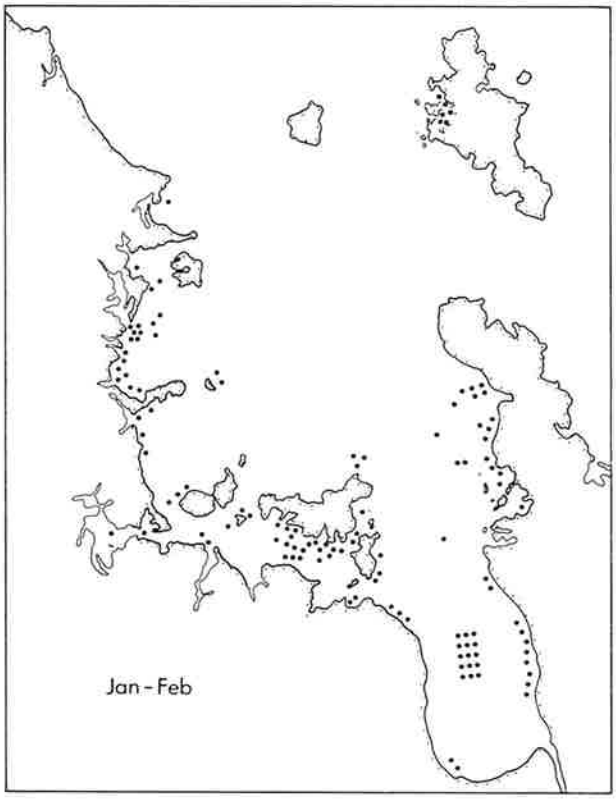
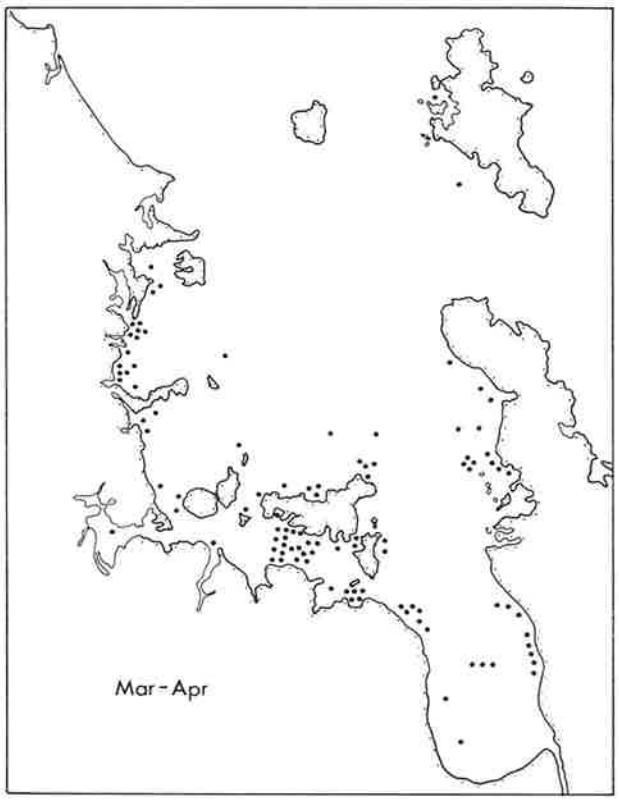
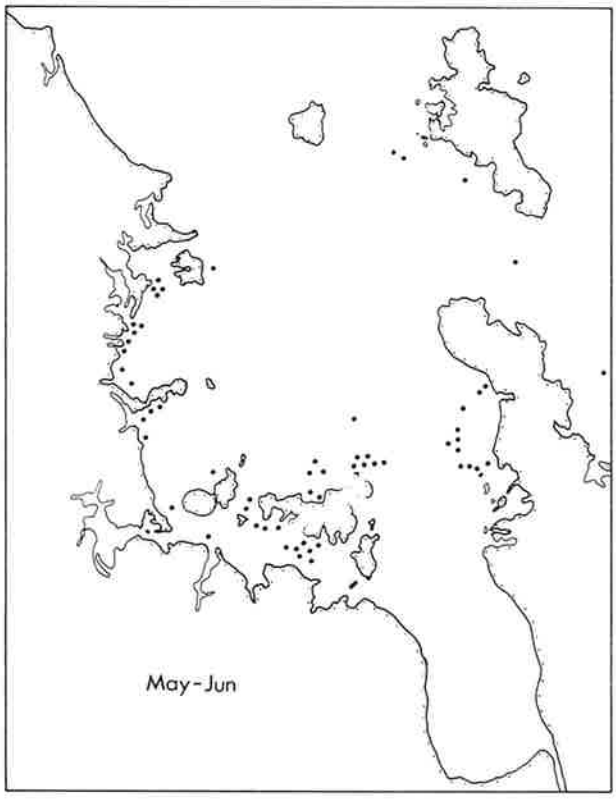


Fig. 3: Seasonal variation in the number of tagged snapper recaptured by different fishing methods.


Jan - Feb


Mar - Apr


May - Jun

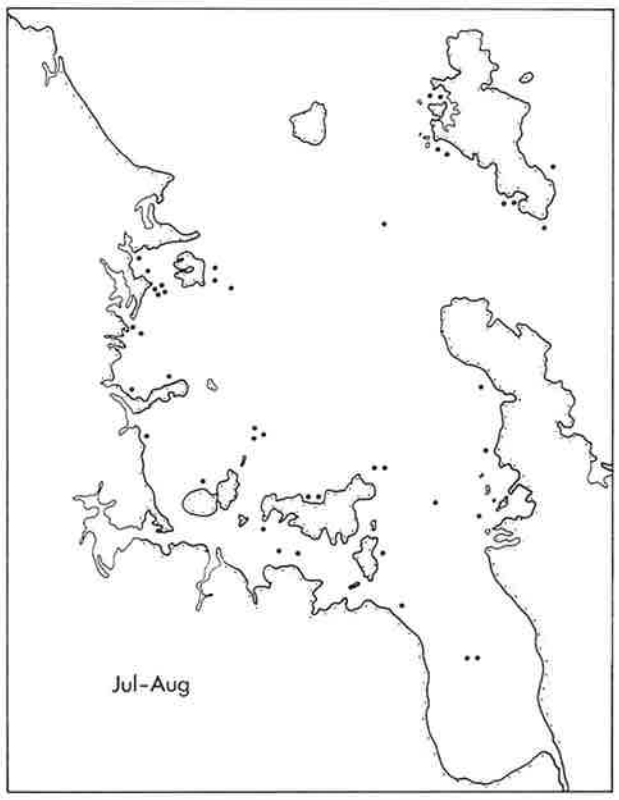

Jul - Aug

Fig. 4 (above and left): Positions of recaptures of tagged snapper in the Hauraki Gulf. Each map is a summation of recoveries during 1974–79.

numbers recorded were comparable to those of the preceding 4 months. Recaptures from the eastern gulf were generally taken further offshore than earlier in the year.

The lowest number of recaptures (45) in a 2-month period was in July and August. Returns were particularly low from the eastern gulf. However, at Great Barrier Island more were recorded than in any other period.

In September and October there were 95 recaptures. Many more were made along the eastern and western sides and north of Waiheke Island than in July and August, but in the southern part (Tamaki Strait and Firth of Thames) there was no increase, and at Great Barrier Island only 1 recapture was made.

Recaptures in November and December further increased to 137, with many recorded in most of the area from Waiheke Island northwards, but, again, few in the southern gulf. The overall distribution showed recaptures to be further offshore than at any other time of the year.

In relation to the geographical distribution of tagged snapper recaptures, it should be noted that a single fisherman returned 45 tags together, caught by Danish seining "between Thumb Point and the Motukawao Islands" over a period of about a year. These data, which could not be plotted because recovery dates were unknown, make the numbers of returns shown from the eastern gulf in Fig. 4 too low.

Figure 5 shows the numbers of tags returned each month in 6 subareas of the Hauraki Gulf. The subareas are defined in Fig. 1 in Crossland (1980a). Three of the subareas, Coromandel, Waiheke, and Kawau, showed seasonal peaks in recaptures during spring (October-December) and 2 subareas, Tamaki and Firth, showed peaks in summer (January-March). The number of recaptures from the sixth subarea, Rangitoto, was low and did not show any distinct peak.

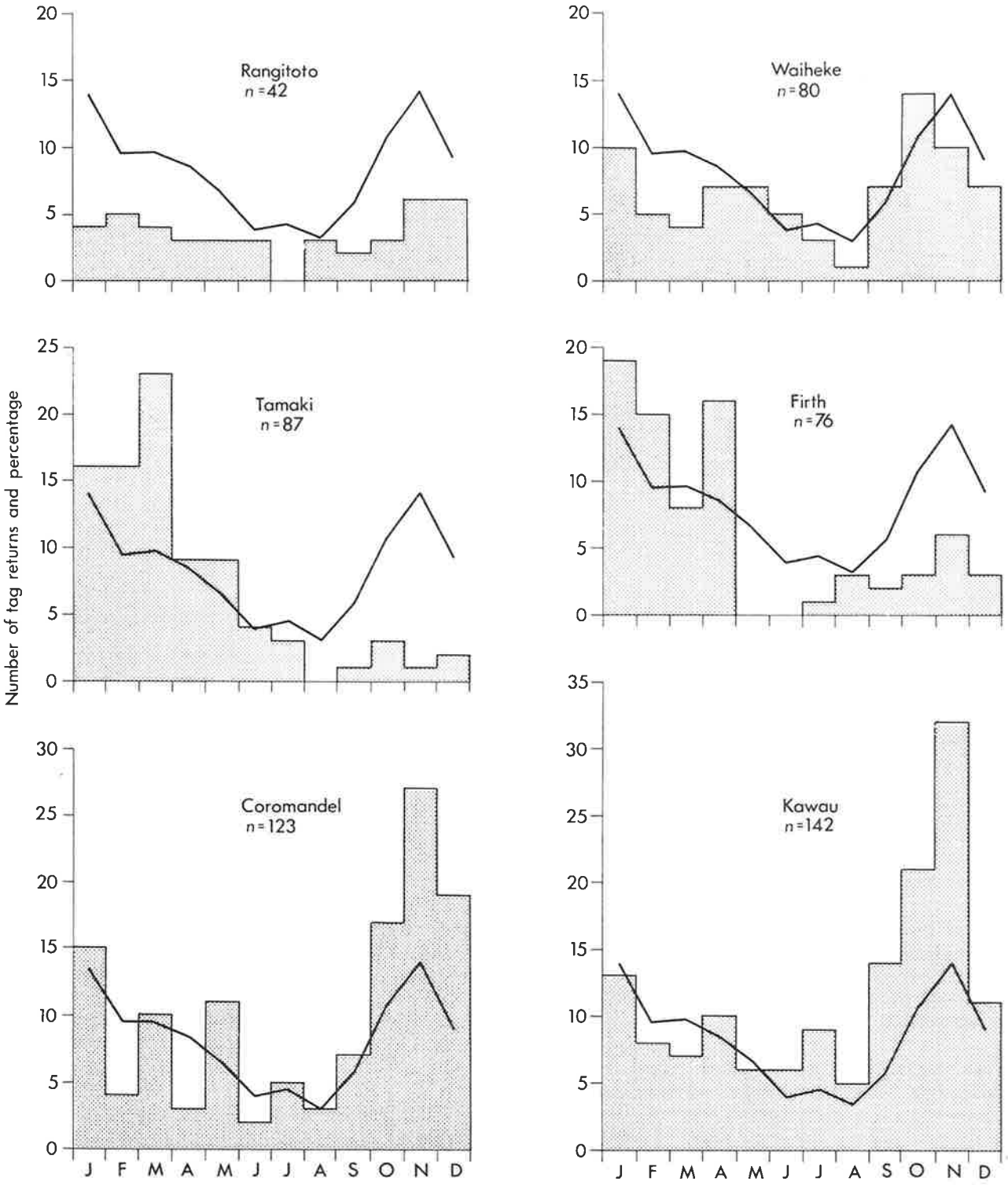


Fig. 5: Monthly number of tag returns for different subareas of the Hauraki Gulf (histograms) compared with the overall monthly return percentage (curve).

Distances and directions of movement

Most tagged fish were recaptured close to the tagging site. Of 609 returns where the recovery details were known accurately, 373 (61%) were recaptured within 5 nautical miles (n miles) (9 km) of the tagging site, 170 (28%) between 6 and 20 n miles (11–37 km), 55 (9%) between 21 and 50 n miles (39–93 km), and 11 (2%) more than 50 n miles from the tagging site. There was no relationship between time at liberty or size of fish and distance travelled.

Movements of tagged snapper were assumed to be represented by the most direct route between tagging site and recapture position. Plots made of all movements greater than 5 n miles showed that these were complex, but seasonal patterns were apparent. A schematic representation of movements based on recaptures made in different 3-month periods is given in Fig. 6.

A difficulty in analysing movement data, if there is a long period between tagging and recapture, is the uncertainty of when the observed movement took place in the intervening period. To minimise this problem the movement patterns in Fig. 6 were mainly based on results obtained from fish tagged as short a time as possible before the corresponding recapture period. Thus, data from fish tagged on the 3 October cruises and in February 1974 were used for the January-March quarter, data from the February 1974 cruise for the April-June quarter, data from the 2 June cruises for the July-September quarter, and data from the August 1974, September 1975, and the 3 October cruises for the October-December quarter.

The arrows in Fig. 6 represent directions of travel and not individual movements. The number and closeness of arrows reflect the importance of different movements based on the number of times such movement was observed.

In summer (January-March) most movements were southwards, particularly into the Firth of Thames and Tamaki Strait. Most of the fish entering the firth were from the eastern gulf, but some came from the western side. In autumn (April-June) there was some further movement into the Firth of Thames, but only during April. Thereafter, movements in the eastern and central gulf were mainly northwards. Some fish moved to as far as Great Barrier Island. Predominantly northward movements continued during winter (July-September) in all parts of the gulf. In spring (October-December) there were more movements than at any other time of year. Most of these were outwards from inshore tagging sites to deeper water. In the eastern gulf tagged fish moved westwards from inside the Motukawao Group to outside these islands and from the Firth of Thames northwards towards the Motukawao Group. From the south-western gulf movements were northwards towards Tiritiri Matangi Island. North of Whangaparaoa Peninsula there was an eastward movement to the area between Kawau Island and Tiritiri Matangi Island. Some fish also moved to this area from the Firth of Thames.

The assumed movements of the 11 fish which were recaptured more than 50 n miles from the tagging site are shown in Fig. 7. Seven of them moved through Colville Channel towards the Bay of Plenty and 4 moved north-west. Fish making long-distance movements ranged in length from 27 to 44 cm. In addition, 1 tag returned from a fish shop was reported to have been from a fish caught in Manukau Harbour. This, I believe, is probably an error.

Distribution and movements

The analysis of the 707 tag returns in this study has confirmed earlier findings by Paul (1967), Crossland (1976), and Tong (1978) that generally snapper do not move long distances. However, within the Hauraki Gulf snapper are quite mobile and their local movements have a profound effect on the fishery as a whole and its different components individually.

Any discussion of movements and the distribution of snapper based on tag returns at different times of year must take into account the peculiarities of the regulations controlling the fishery in the Hauraki Gulf and the different fishing methods. In fishery statistical area 007 (see Fig. 1) Danish seining and trawling are prohibited and all the catch from this area is taken by commercial long-liners and set netters or by amateurs. In area 006 Danish seining is allowed, and in the part north of the "trawling line" in Fig. 1 trawling is also allowed between March and September.

Fig. 6: Patterns of movements of tagged snapper in the Hauraki Gulf.

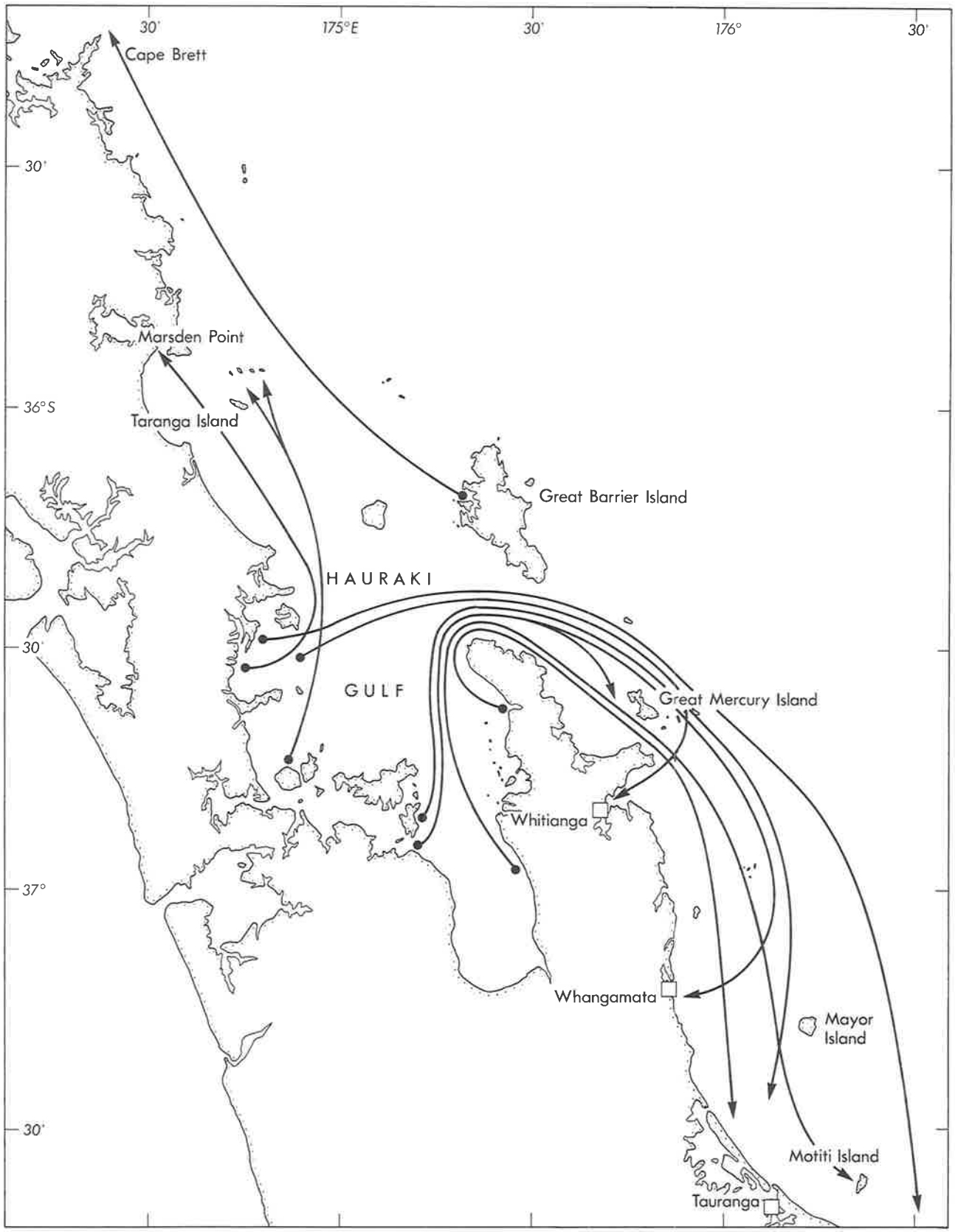


Fig. 7: Long-distance movements of snapper tagged in the Hauraki Gulf.

Many of the recaptures of tagged snapper by seiners were clustered close to the boundary between areas 006 and 007. This pattern reflects the combined effects of the regulations and the distribution of snapper in the inner gulf. Snapper are most numerous in the inshore parts (Crossland 1976) with a rapidly decreasing abundance as the depth increases towards the central parts of the gulf. On the eastern side there were more recaptures by seiners than on the western. Rather than indicating a greater abundance of snapper in the east, this probably results from the boundary of 006 and 007 being closer to the shore on that side.

Although long-liners are not restricted in the areas in which they can fish, their tag returns may not always be representative of the density of snapper by area and season. For example, lower catches in winter may not indicate that snapper are less abundant, but only that they are feeding less. Fish behaviour may also affect catchability at other times of the year. During spawning snapper may become less wary and the increased catches by seiners in spring may partly result from this.

Bearing in mind factors such as those above, and taking into account knowledge of the abundance of snapper accumulated during the tagging cruises and of their spawning habits (Crossland 1977, 1980b), I propose the following theory of adult snapper distribution and movements in the Hauraki Gulf.

Summer

After spawning, which usually finishes during January in areas 006 and 007, large numbers of snapper move from the spawning grounds on the edges of the central gulf into the shallows, where they spend the next 3–4 months. This post-breeding period, with its high water temperatures, is probably the time when most of the annual growth increment takes place. Many snapper are found in Tamaki Strait and along the western shore; others penetrate harbours such as the Waitemata or move up the Firth of Thames to as far as the Waihou River. This inshore movement results in low catches by Danish seiners during summer, but set netters make large catches, mainly in the Firth of Thames. However, fishing pressure by amateurs during this, the holiday, period easily exceeds that of other methods, particularly along the western shoreline near the large population centres.

Autumn

Snapper are still found in the shallows throughout the gulf during April, but thereafter many of them move out to deeper water. This movement is most noticeable in the Firth of Thames and by June snapper are absent south of Ponui Island. A similar pattern occurs in Tamaki Strait, but not all fish move out. Snapper from these areas and along the eastern side of the gulf move north, some of them to as far as Great Barrier Island and a few out through Colville Channel. However, most of the stock probably remains in the inner gulf, along the eastern shore between Coromandel Harbour and Colville Bay. In other parts of areas 006 and 007, though a few fish may move offshore, there is much less movement and snapper remain in large numbers north of Waiheke Island and along the whole of the western shore; they are particularly abundant in Whangaparaoa Bay and through Inner Channel to Kawau Island.

The autumnal movement out of the southern gulf might be attributed to falling sea temperatures, but temperature cannot be the only factor. Other parts of the gulf, such as the south-west side, record lower temperatures (Paul 1968), but snapper remain there.

Snapper catches are low during autumn because much of the stock is unavailable to Danish seiners or is dispersed over the deeper parts of the gulf.

Winter

Some movement out of the inner gulf continues during early winter. The numbers of resident snapper are probably lowest for the whole year during July and August, but they still constitute the majority of the stock. At the end of winter a return movement begins along the eastern side, with some fish moving southwards to the entrance of the Firth of Thames. Other snapper probably enter Tamaki Strait at this time.

During winter virtually all snapper landings from areas 006 and 007 are made by Danish seiners and long-liners, which maintain low but steady catches.

Spring

This is the spawning season for snapper and the time when the largest total catches are made. The late winter movement continues during October and becomes more generalised, with some snapper moving from Great Barrier Island to the southern gulf. Snapper are now congregated in the inner areas, feeding heavily, and spread widely inside and outside the many island groups. An offshore movement now occurs on to the spawning grounds. From Tamaki Strait snapper move out to spawn north of Waiheke Island. From Rangitoto Island to Whangaparaoa Peninsula along the western shore there is a movement out to the area between the Noises and Tiritiri Matangi Island. Similarly, snapper from Whangaparaoa Bay and Inner

Channel move out to spawn between Tiritiri Matangi Island and Kawau Island. In the eastern gulf there is another spawning ground to the west of the Motukawao Group which can extend southwards to the northern part of the Firth of Thames. Snapper move into this area from inside the islands along the Coromandel coast, from the Firth of Thames, and also from Tamaki Strait.

Snapper are serial spawners; so the movements described above probably take place many times during spring as successive batches of eggs are spawned. Thus some part of the stock is present over the whole area at any one time.

Tag returns by long-liners rose sharply to a peak in October, but for Danish seiners the peak was in November. This sequence follows the pattern of spawning which begins in the south in area 007, where long-liners can fish but seiners cannot, and occurs later in the west and east of the gulf along the edges of area 006, where the stock becomes vulnerable to seiners. During December, though snapper are still spawning heavily, there is a decrease in landings by these 2 methods, probably because of less effort during the Christmas period.

If the spring has been warm and spawning has occurred early, some fish may begin to move into the shallows in late December, which contributes to a rise in catches by amateurs at this time.

Conclusion

My conclusion from this study is that most snapper are resident in a particular area and make only local movements associated with feeding and spawning, but that there is also a mixing process involving at any one time a small proportion of fish. These move into neighbouring areas and may or may not return. Fish in the neighbouring areas behave in a similar way. This process, with occasional long-distance movements, serves to maintain a continuous stock wherever there are no physical barriers or limiting environmental factors.

Acknowledgments

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